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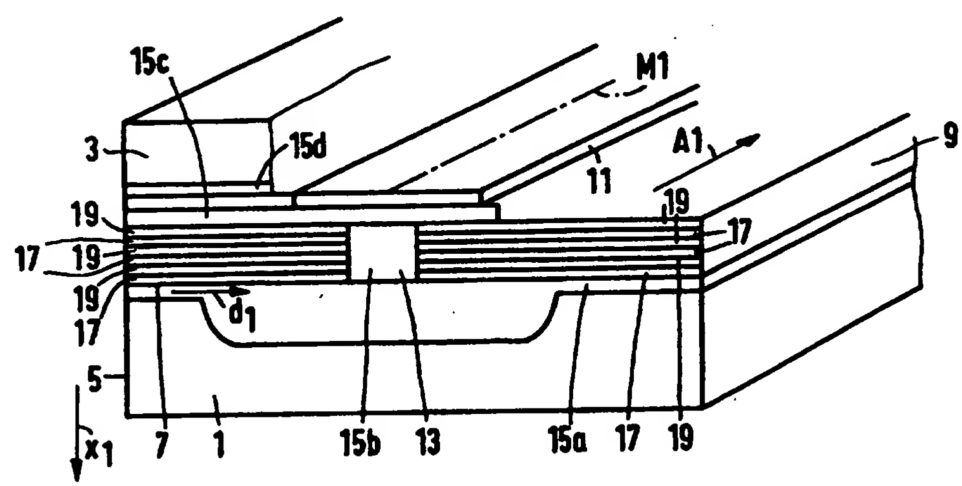
(54) Title: MAGNETIC HEAD HAVING A LAMINATED FLUX GUIDE, AND DEVICE PROVIDED WITH THE MAGNETIC HEAD



(57) Abstract

Magnetic head having a head face (5) and comprising a magnetic yoke which is provided with an MR sensor (11) having an easy axis of magnetization (M_1), and a flux guide (7;, 9). To optimally inhibit the occurrence of domain walls, the flux guide comprises a pair of exchange-coupled layers, a first layer of which is a soft-magnetic layer (17) and a second layer is an anti-ferromagnetic or ferrimagnetic layer (19).

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Magnetic head having a laminated flux guide, and device provided with the magnetic head.

The invention relates to a magnetic head having a head face and comprising a magnetoresistive sensor and at least a laminated flux guide for co-operation with the magnetoresistive sensor, which flux guide comprises a soft-magnetic layer.

A magnetic head of this type is known as a thin-film magnetic head from IEEE Transactions on Magnetics, Vol. 28, No. 5, September '92. The known magnetic head is provided with a first and a second flux guide, and a magnetoresistive sensor bridging a space between the two flux guides. The sensor is constituted by a layer of NiFe (permalloy). The flux guides are constituted by a layer structure of alternately soft-magnetic and non-magnetic material so that each flux guide consists of magnetostatically coupled magnetic layers.

A problem of a magnetic head provided with a magnetoresistive sensor is the occurrence of Barkhausen noise in the sensor and/or the flux guide or flux guides present, due to discontinuous movements of domain walls. Barkhausen noise results in a non-linear distortion of a signal which has been read. Although a flux guide consisting of magnetostatically coupled layers has an enhanced magnetic stability, there remains a considerable risk of unwanted domain walls in the flux guide.

It is an object of the invention to provide a magnetic head of the type described in the opening paragraph, which substantially precludes the occurrence of domain walls in a flux guide.

In accordance with a first aspect, the magnetic head according to the invention is characterized in that the flux guide comprises an anti-ferromagnetic layer which is in direct contact with the soft-magnetic layer, the soft-magnetic layer and the anti-ferromagnetic layer constituting a pair of exchange-coupled layers. For example, an Ni-Mn alloy, Fe-Mn alloy, Ni oxide, Co oxide or Ni-Co oxide may be used as anti-ferromagnetic materials.

In accordance with a second aspect, the magnetic head according to the

invention is characterized in that the flux guide comprises a ferrimagnetic layer which is in direct contact with the soft-magnetic layer, the soft-magnetic layer and the ferrimagnetic layer constituting a pair of exchange-coupled layers. For example, a Tb-Co alloy or Tb-Fe-Co alloy is suitable as a ferrimagnetic material.

The invention is based on the recognition that the flux guide is given a unidirectional anisotropy by means of exchange biasing so that there is a unique lowest-energy direction for the magnetization in the flux guide, in which domain walls are entirely or substantially entirely absent. It has been found that the flux guide in the magnetic head according to the invention is magnetically stable and does not produce any or hardly any noise.

The magnetic head according to the invention is suitable for reading audio, video or data information recorded on a magnetic record carrier. An exchange-biased sensor may be used as a magnetoresistive sensor which, together with a flux guide, constitutes a magnetic yoke.

For example, an Ni-Fe alloy, a Co alloy such as Co-Nb-Zr, or an Fe alloy such as Fe-Nb-Si-N, Fe-Ta-N or Fe-Al-N is suitable as a soft-magnetic material in the magnetic head according to the invention.

It is to be noted that it is known per se from IEEE, Vol. 25, No. 5, September 1989 to inhibit domain activities in a narrow-track MR element by using an exchange-biased sensor. This publication does not pay any attention to flux guides.

An embodiment of the magnetic head according to the invention is characterized in that the flux guide has a unidirectional anisotropy which is at least substantially perpendicular to a flux transport direction in the flux guide. The flux transport direction is understood to mean the direction of the magnetic field in the flux guide coming from the magnetic record carrier during use of the magnetic head. In this embodiment, an optimal combination of magnetic stability and permeability is achieved. Generally, the sensor will have an easy axis of magnetization which is oriented perpendicularly or substantially perpendicularly with respect to the flux transport direction in the flux guide. The unidirectional anisotropy in the flux guide will thus usually extend at least substantially parallel to the easy axis of magnetization of the sensor.

An embodiment of the magnetic head according to the invention is characterized in that the flux guide comprises several pairs of exchange-coupled layers. At a given total magnetic thickness of the flux guide, the number of exchange-coupled layers defines the size of the bias field in the flux guide, which is approximately inversely

proportional to the thickness of the exchange-coupled soft-magnetic layer. Therefore, there is a great freedom of optimization. An important advantage is that high-frequency losses in the flux guide are limited by using thinner layers.

An embodiment of the magnetic head according to the invention is characterized in that the flux guide comprises a combination of layers which is constituted by the pair of exchange-coupled layers, a non-magnetic layer and a further soft-magnetic layer, the non-magnetic layer extending between, and being in contact with, the soft-magnetic layer and the further soft-magnetic layer. The combination of layers created in this embodiment decreases the magnetostatic energy in the flux guide built up as a packet of layers, which has a positive effect on the magnetic stability of the flux guide.

An embodiment of the magnetic head according to the invention is characterized in that the flux guide comprises several combinations of layers as defined in the previous embodiment, the combinations of layers being mutually separated by a non-magnetic intermediate layer. The layer structure used in this embodiment gives it all the previously mentioned advantages relating to the bias field, limited high-frequency losses and satisfactory magnetic stability.

An embodiment of the magnetic head according to the invention is characterized in that the flux guide extends from the head face, while a further flux guide is present, and the magnetoresistive element bridges a space which is present between the flux guide and the further flux guide, the further flux guide corresponding to the previously defined flux guide. In practice, further flux guides are frequently used to inhibit magnetic flux losses in magnetic circuits as much as possible.

The invention also relates to a device for reading a magnetic record carrier, comprising a magnetic head according to the invention.

These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter.

In the drawings:

Fig. 1 is a diagrammatic perspective view of a first embodiment of the magnetic head according to the invention,

Fig. 2 is a diagrammatic cross-section of a second embodiment of the magnetic head according to the invention,

Fig. 3 is a cross-section taken on the line III-III of the magnetic head

shown in Fig. 2,

Fig. 4 is a diagrammatic cross-section of a third embodiment of the magnetic head according to the invention, and

Fig. 5 is a partly elevational, partly cross-sectional view of a device according to the invention.

The magnetic head according to the invention, shown in Fig. 1, comprises a substrate 1 of a magnetically permeable material such as ferrite, for example Ni-Zn ferrite, a thin-film structure provided in layers on the substrate 1 and a protective layer or protective body 3, and is provided with a head face 5. The film structure comprises two flux guides 7 and 9, a first flux guide 7 of which is contiguous to the head face 5 and a second flux guide 9 is spaced apart therefrom and from the first flux guide 7. The film structure also comprises a magnetoresistive sensor 11, referred to as MR sensor, which extends opposite the flux guides 7 and 9 and bridges a space 13 between the two flux guides. When a magnetic information or record carrier such as a magnetic tape or disc moving along or on the head face 5 in a direction x_1 is scanned, a magnetic field coming from the record carrier is transported by the flux guides 7 and 9 in a direction d_1 which is substantially transverse to the head face 5, while the flux is guided through the MR sensor 11. The magnetic flux is returned to the record carrier via the magnetically conducting substrate 1. Insulation layers 15a, 15b, 15c and 15d of an electrically insulating material such as SiO_2 or Al_2O_3 are present between the substrate 1 and the flux guides 7 and 9, in the space 13, between the flux guides 7 and 9 and the MR sensor 11, and between the MR sensor 11 and the protective body 3. The MR sensor 11 comprising a layer of a magnetoresistive material, for example an Ni-Fe alloy, has an easy axis of magnetization M_1 which is substantially perpendicular to the flux transport direction d_1.

The flux guides 7 and 9, which have a similar construction relative to each other, comprise three pairs of a exchange-coupled layers each in this embodiment, each pair comprising a soft-magnetic layer 17 and an anti-ferromagnetic layer 19 engaging the layer 17. Due to exchange biasing, both flux guides 7 and 9 have a unidirectional anisotropy A_1 which is substantially perpendicular to the flux transport direction d_1 in the flux guides 7 and 9 and thus extend at least substantially parallel to the easy axis M_1 of the MR sensor 11. In this embodiment, the soft-magnetic layer 17 is formed from an Ni-Fe alloy and the anti-ferromagnetic layer 19 is formed from an Ni-Mn alloy. The materials may be provided by means of known deposition techniques such as sputtering, vapour deposition or chemical

vapour deposition. Instead of three pairs of exchange-coupled layers, a larger or smaller number of pairs may be used within the scope of the invention.

The magnetic head according to the invention, shown in Figs. 2 and 3, is a thin-film magnetic head comprising a substrate 101, in this embodiment of a non-magnetic material, for example Al_2O_3.TiC, on which a multilayer structure and a protective block 103 of a non-magnetic material, for example Al_2O_3.TiC is provided. The magnetic head has a head face 105 for moving a magnetic record carrier 107, particularly a magnetic tape in a direction x_2.

The multilayer structure, which extends between the substrate 101 and the protective block 103, comprises a magnetoresistive layer 159 of a magnetically anisotropic material, for example Ni-Fe, which constitutes an elongated magnetoresistive element 111 between two end portions 159a and 159b, with a longitudinal axis 111a extending from one end portion to the other end portion. The magnetoresistive element 111, referred to as MR sensor, has an easy axis magnetization, denoted by M_2, extending parallel to the longitudinal axis 111a. The direction of magnetization is denoted by means of the vector $\overline{M}_2$. An electrically conducting layer 153a of, for example Au comprising a plurality of equipotential strips 153 is provided on one side 111b of the element 111. The equipotential strips extend at an angle of 45° to the longitudinal axis 111a. The electrically conducting layer 153a has two connection tracks 153a1 and 153a2 to which a current source or voltage source may be connected.

A non-magnetic insulation layer 519 of, for example Al_2O_3 or SiO_2 is present between the substrate 101 and the magnetoresistive layer 159. The multilayer structure further comprises a flux guide 107 contiguous to the head face 105 and, spaced apart therefrom, a second flux guide 109. A space 113 present between the two flux guides is bridged by the MR sensor 111, the first flux guide 107 serving for guiding a magnetic field comprising information and originating from the magnetic medium 107 in a flux transport direction d_2 to the MR sensor 111. Insulating material 120, for example SiO_2, is provided in the space 113 as well as between the MR sensor 111 and the flux guides 107 and 109, and between the flux guides 107 and 109 and a third flux guide 110. The flux transport direction in the third flux guide is denoted by the arrow d_3.

The flux guides 107, 109 and 110 which, together with the MR sensor 111, constitute a magnetic yoke, comprise a pair of exchange-coupled layers each, formed by a soft-magnetic layer 217 and a ferrimagnetic layer 219. In this embodiment, the soft-magnetic layer 217 is constituted by a Co-Nb-Zr alloy and the ferrimagnetic layer 219 is

constituted by a Tb-Co alloy. Due to exchange biasing, the flux guides 107, 109 and 110 have a unidirectional anisotropy A_2 which extends parallel or substantially parallel to the easy axis of magnetization M_2 of the MR sensor 111. Instead of a pair of said layers per flux guide, several pairs may alternatively be used. If less stringent requirements are imposed on the magnetic head, one or two flux guides, notably the flux guide 110, may be formed completely from a soft-magnetic material, but then the optimal advantage of the use of exchange-coupled layer is of course not achieved.

The magnetic head according to the invention, shown in Fig. 4, comprises a magnetically conducting substrate 201 of ferrite on which a layer structure is provided. This layer structure comprises a magnetoresistive sensor 211, referred to as MR sensor 211, two flux guides 207 and 209, a test and/or bias guide 251 and also a plurality of insulation layers of an electrically insulating, non-magnetic material 220 such as quartz, so as to insulate the substrate 201, the MR sensor 211, the flux guides 207 and 209 and the guide 251 with respect to each other. The layer structure is protected by a counterblock 203 of, for example $BaTiO_3$ or $CaTiO_3$, while an insulation layer 230 extends between the layer structure and the counterblock 203. A front side of the magnetic head is provided with a head face 205.

In this embodiment, the flux guides 207 and 208 each consist of two combinations of layers, with a non-magnetic intermediate layer 221 of, for example SiO_2 or Al_2O_3 extending between the two combinations. Each combination consists of a stack of four layers, namely an anti-ferromagnetic or ferrimagnetic layer 219, a soft-magnetic layer 217, a non-magnetic layer 223 and a further soft-magnetic layer 225. Instead of two such combinations, more combinations may be used alternatively, with an intermediate layer 221 extending between each combination. By way of example, the layer 219 is formed from an Fe-Mn alloy and the layers 217 and 225 are formed from an Fe alloy. The non-magnetic layer 223 is formed from, for example SiO_2 or Al_2O_3. The flux guides 207 and 209 have a flux transport direction d_4 which is substantially parallel to the head face 205 and has a unidirectional anisotropy in accordance with a direction A_3 which, in Fig. 4, is substantially perpendicular to the plane of the drawing. The MR sensor 211 is, for example, an exchange-biased sensor.

The device shown in Fig. 5 is a magnetic tape apparatus 350 which is suitable for co-operation with a magnetic tape cassette. Such a cassette has a magnetic tape which is suitable for storing information in an analog and/or digital form. The apparatus 350, which is provided with a holder 352 for accommodating the cassette, constitutes a magnetic

tape system together with the cassette. Two reel spindles 354 and 356 for co-operation with reel hubs of the cassette are present in the apparatus 350. During use of the apparatus 350, the magnetic tape is moved along a magnetic head 400 according to the invention, used in the apparatus 350. To this end, the apparatus 350 is provided with two capstans 358 and 360 and two pressure rolls 362 and 364 co-operating with the capstans.

It is to be noted that the invention is not limited to the embodiments shown. For example, the magnetic head according to the invention may comprise several MR sensors and even a large number of MR sensors and a matching number of flux guides, instead of one MR sensor. Instead of one or more MR sensors, the magnetic head may alternatively have one or more inductive transducing elements.

CLAIMS:

1. A magnetic head having a head face and comprising a magnetoresistive sensor and at least a laminated flux guide for co-operation with the magnetoresistive sensor, which flux guide comprises a soft-magnetic layer, characterized in that the flux guide comprises an anti-ferromagnetic layer which is in direct contact with the soft-magnetic layer, the soft-magnetic layer and the anti-ferromagnetic layer constituting a pair of exchange-coupled layers.

2. A magnetic head having a head face and comprising a magnetoresistive sensor and at least a laminated flux guide for co-operation with the magnetoresistive sensor, which flux guide comprises a soft-magnetic layer, characterized in that the flux guide comprises a ferrimagnetic layer which is in direct contact with the soft-magnetic layer, the soft-magnetic layer and the ferrimagnetic layer constituting a pair of exchange-coupled layers.

3. A magnetic head as claimed in Claim 1 or 2, characterized in that the flux guide has a unidirectional anisotropy which is at least substantially perpendicular to a flux transport direction in the flux guide.

4. A magnetic head as claimed in Claim 1, 2 or 3, characterized in that the flux guide comprises several pairs of exchange-coupled layers.

5. A magnetic head as claimed in Claim 1, 2, 3 or 4, characterized in that the flux guide comprises a combination of layers which is constituted by the pair of exchange-coupled layers, a non-magnetic layer and a further soft-magnetic layer, the non-magnetic layer extending between, and being in contact with, the soft-magnetic layer and the further soft-magnetic layer.

6. A magnetic head as claimed in Claim 5, characterized in that the flux guide comprises several combinations of layers as defined in Claim 5, the combinations of layers being mutually separated by a non-magnetic intermediate layer.

7. A magnetic head as claimed in any one of Claims 1 to 6, characterized in that the flux guide extends from the head face, while a further flux guide is present, and the magnetoresistive element bridges a space between the flux guide and the further flux guide, the further flux guide corresponding to the flux guide as defined in any one of Claims 1 to 6.

8. A device for reading a magnetic record carrier, comprising a magnetic head as claimed in any one of the preceding Claims.

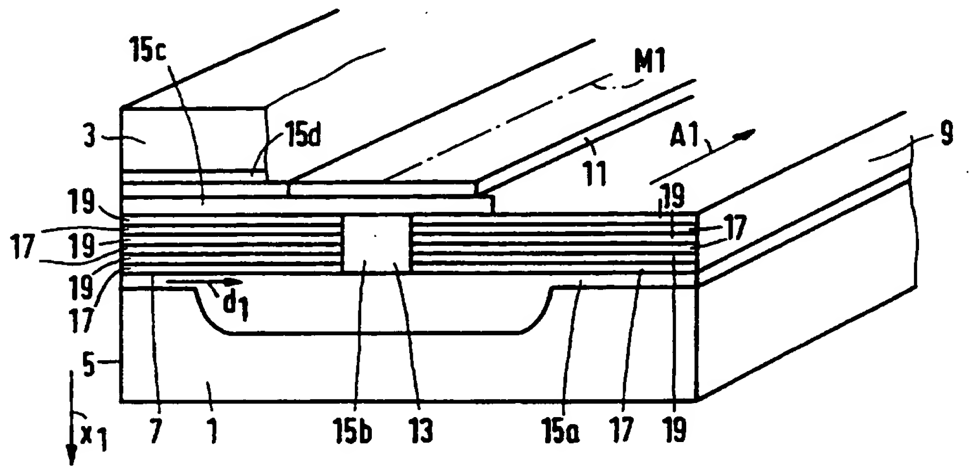
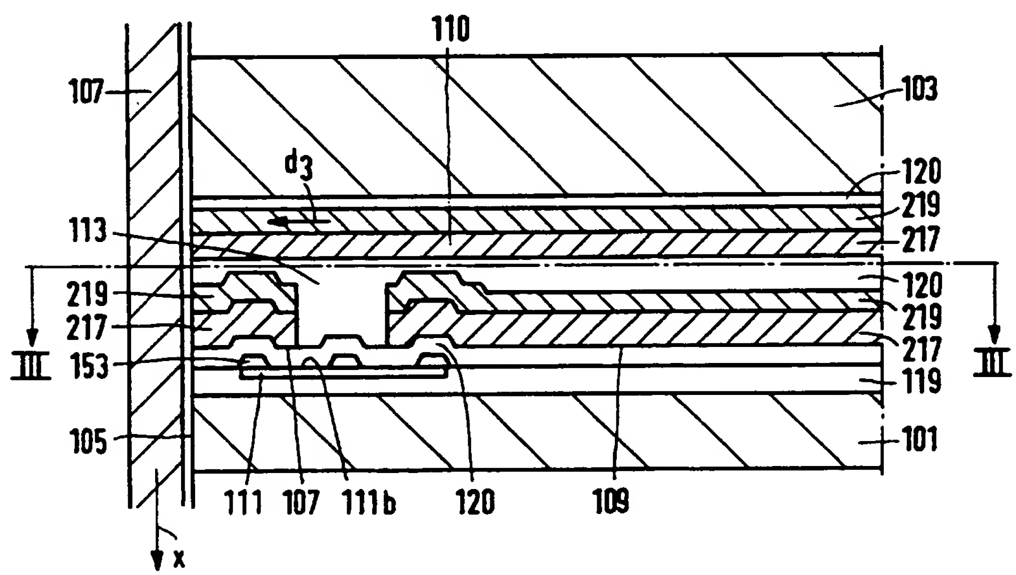

15c
M1
3
15d
A1
9
11
19
19
17
19
17
19
17
19
17
d1
5
x1
7
1
15b
13
15a
17
19

FIG. 1


110
107
103
d3
120
219
113
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219
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219
III
153
217
III
119
105
101
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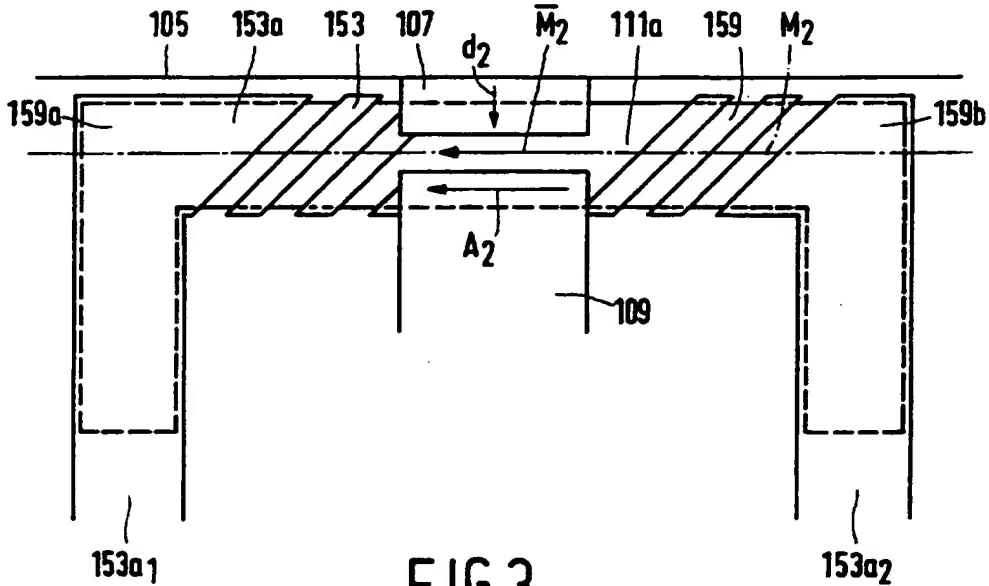
111b
120
109
x

FIG. 2


105
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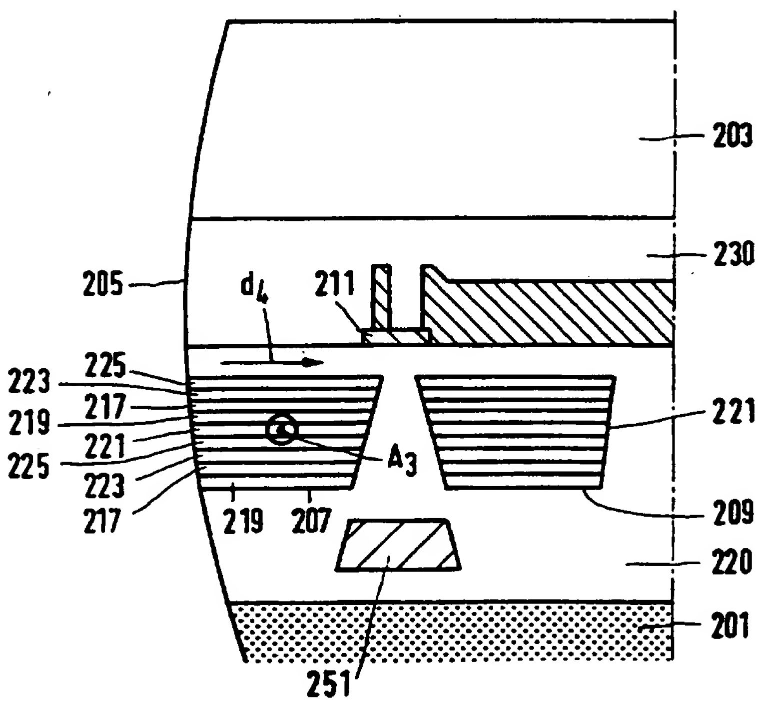
M2
111a
159
M2
159a
159b
A2
109
153a1
153a2

FIG.3


203
230
205
d4
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219
221
225
223
217
A3
221
219
207
209
220
201
251

FIG.4

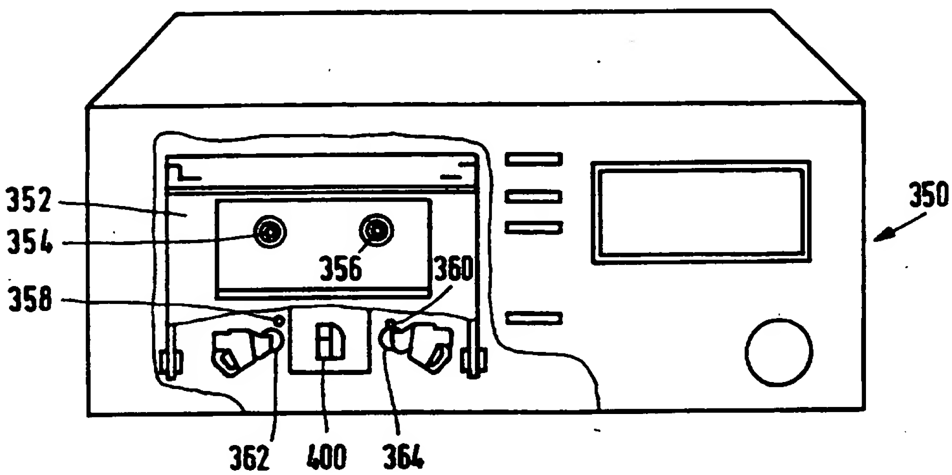

FIG.5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB 96/01133

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: G11B 5/31, G11B 5/39
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: G11B, H01F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EDOC, JAPIO, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0427171 A2 (INTERNATIONAL BUSINESS MACHINES CORPORATION), 15 May 1991 (15.05.91), page 4, line 20 - page 5, line 5; page 6, line 57 - page 7, line 17; page 9, line 38 - page 10, line 27	1-8
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X	Patent Abstracts of Japan, Vol 18,No 685, P-1848, abstract of JP,A,6-267034 (FUJITSU LTD), 22 Sept 1994 (22.09.94)	1,8
A		2-7
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[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
20 February 1997	26 -02- 1997

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB 96/01133

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	IEEE TRANSACTIONS ON MAGNETICS, Volume 28, No 5, Sept 1992, C. Tsang, M. Krounbi, "STUDY OF RECESSED MR SENSORS WITH UNLAMINATED AND MULTI-LAMINATED FLUX-GUIDES", page 2289 - page 2291, Cited in the application --	1-8
A	EP 0064786 A2 (N.V. PHILIPS' GLOEILAMPENFABRIEKEN), 17 November 1982 (17.11.82) --	1-8

INTERNATIONAL SEARCH REPORT
Information on patent family members

03/02/97

International application No.
PCT/IB 96/01133

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		US-A- 5032945	16/07/91
		US-A- 5331728	26/07/94
		US-A- 5388019	07/02/95
EP-A2- 0064786	17/11/82	JP-A- 57203979	14/12/82
		NL-A- 8102148	01/12/82
		US-A- 4489357	18/12/84